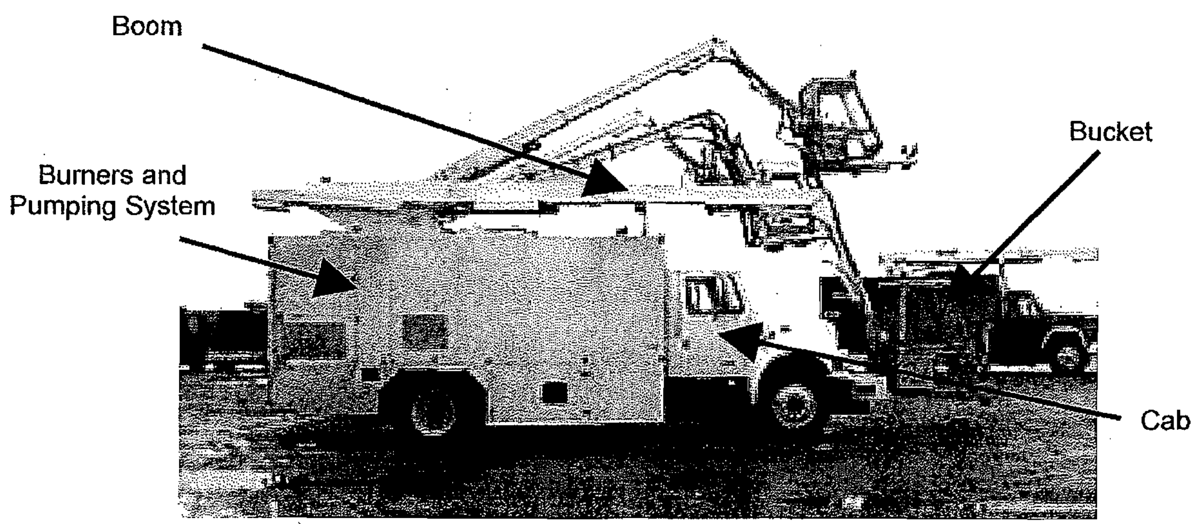
Deicing Equipment and Fluids

Overview of Deicing Vehicles

Deicing vehicles – or "deicers" – are complex pieces of equipment that contain several integrated systems, all of which must work together in order to accomplish the deicing process. These include the following:

- Vehicle Chassis: The vehicle platform contains the power train (engine, transmission, etc.), cab, and the other components found in other vehicles. The vehicle's engine may take diesel or gasoline fuel.
- Glycol Handling Systems: This system contains the storage tanks for glycol, the pumping equipment, and plumbing to transport the glycol from the storage tanks to the nozzles. Some deicers contain two separate glycol-handling systems – one for deicing fluid, and one for anti-icing fluid.
- Burners: The burners provide heat to Type I fluid before it is sprayed onto the aircraft (remember – Type IV anti-icing fluid is not heated; it is applied cold when it is used). The burners usually have a separate fueling system from the vehicle's engine, and may take a different type of fuel (e.g., diesel vs. gasoline).
- Lift Platform and Articulating Arm: The boom and bucket provide the required elevation to the deicing employee. A harness and lanyard are always required whenever an employee is in the deicing bucket. One set of boom controls is located in the bucket and another set on the vehicle itself.



Operation of Deicing Equipment

Boom Controls

Deicers are equipped with two sets of boom and bucket controls – one in the bucket (upper) and one on the vehicle near the ground (lower). Both sets of controls shall be plainly marked as to their function. Lower level controls shall not be operated unless permission has been obtained from the employee in the bucket, except in case of emergency.

Driving a Deicer

Driving a deicer is a different experience from a personal car or truck. It will take hands-on training and a lot of practice in order to operate it safely around aircraft, other vehicles, and ground personnel. This is especially true during adverse weather conditions that can cause poor visibility and slippery ramp conditions.

General Driving Tips:

- A walk-around inspection must be performed by the operator of a deicer before use.
- Never drive over 5 miles per hour while the boom is extended.
- Do not make sharp turns or drive at excessive speeds.
- Deicers are usually equipped with air brakes, which take longer to stop than the hydraulic brakes used in most cars and trucks.
- Always bring your drivers license to work – it must be shown to supervisors or airport personnel upon request.
- If you are taking medication that might impair your ability, tell your supervisor!
- Follow the alcohol rule...no alcohol within 8 hours of work.
- Only ride in safe and secure vehicle seating.
- Do not drive deicers under jetways or through tunnels.
- Use a guide person whenever needed...such as backing up in the vicinity of aircraft or other vehicles.
- Aircraft and emergency vehicles have the right of way.
- When approaching an aircraft, always perform a 50' and 10' safety stop...then approach the aircraft at a "dead slow speed" (slow walking speed).
- No smoking is allowed in company vehicles.
- Never start the heaters when the deicer is within 100 feet of aircraft or fuel storage facilities.
- The driver of the deicer must not leave the cab while another person is in the bucket.

CAUTION

SSP 110, "GSE Operator Procedure." All Signature Flight Support employees are required to have successfully completed training on each respective piece of equipment, have in their possession a valid driver's license, and obtain airport-restricted driver permits before operating ground support equipment unsupervised.

SSP 114, "Equipment Abuse/Neglect." Signature Flight Support will not tolerate the improper treatment of equipment beyond normal wear. Equipment should be treated with the same care as though it were your own.

SSP 116, "Ramp Vehicle Positive Control Stops." All ramp vehicles/equipment shall be required to perform a mandatory full stop fifty (50) feet from the aircraft perimeter to ensure that the vehicle braking system is fully operational.

Communication

During the deicing operation, two-way radio communication must be maintained at all times between the driver, boom operator and wing walker(s). This will be accomplished with either a vehicle equipped voice activated two-way communication system or two way radios equipped with voice activated boom mikes. Two-way radios other than a vehicle-equipped system must be operated on a dedicated frequency to avoid interference from other Company operations. **If communication between the driver and the employee in the bucket is lost, the driver must STOP immediately until communication is re-established.**

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Description of Deicing and Anti-Icing Fluids

Deicing and anti-icing fluids are known as Freeze Point Depressants (FPDs), which decrease the temperature at which water will freeze. They are propylene-based glycol compounds designed to be sprayed onto the surfaces of aircraft to remove and/or prevent accumulation of snow, ice, and frost. The two types of fluids used at Signature locations are Type I (one) and Type IV (four).

Type I Fluids

Type I fluids are used for deicing aircraft, although they do provide some limited anti-icing protection. They are specifically designed to be diluted with water (generally a 50/50 mixture) and heated prior to being sprayed onto an aircraft.

Characteristics of Type I Deicing Fluids:

- Orange in color
- Free of particulate
- Thin, water-like consistency
- Very limited holdover time
- Always heated prior to application

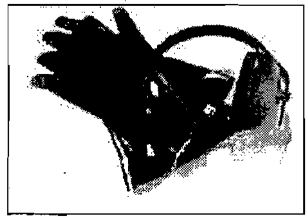
Type IV Fluids

Type IV fluids provide anti-icing protection and contain thickening agents that increase the consistency to that of heavy-weight oil or gel. This consistency allows the fluids to remain on a clean aircraft surface and prevent the build-up of snow, ice, or frost. Type IV fluids are never heated or diluted prior to application. Also, they should not be used on any aircraft with rotation speed of less than 85 knots (generally, any propeller-driven aircraft) because a high speed is needed to "push off" Type IV fluid upon departure.

Characteristics of Type IV Anti-Icing Fluids:

- Light emerald green in color
- Thickened
- Longer holdover times
- Application results in a thick liquid film on surfaces
- Air flow over the wing (shear) causes the fluid to progressively flow off critical wing surfaces prior to take-off
- Never heated prior to application

Personal Protective Equipment (PPE)

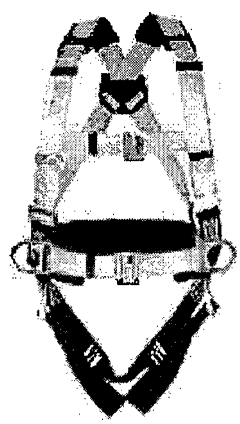


To ensure the safety and health of employees, Signature Flight Support requires the use of Personal Protective Equipment (PPE) during deicing operations. Employees must perform pre-use inspections of all PPE and notify their supervisor of any potential safety hazards.

Fall Protection Program

The BBASSI Health, Safety, and Environmental Manual "Fall Protection Program" outlines the corporate requirements for boom and bucket inspections, personnel training, and design standards for PPE. The base General Manager is responsible for ensuring compliance with the requirements of this program.

Bucket Safety Harness and Lanyard



Each person operating the bucket aerial device (Boom) must wear an approved body harness affixed with an approved shock-absorbing lanyard attached to the approved anchor point located on the boom prior to the movement of the unit or extension of the aerial device. The harness and lanyard must remain connected at all times during the deicing operation and may only be disconnected once the unit is parked and the operator is ready to get out of the bucket. The harness and lanyards must be inspected prior to use and found to be in good condition and not in any way broken or frayed.

Note: For enclosed aerial devices, the manufacturer-installed, four point harness must be utilized.

SSP 304, "Deicing Safety Equipment." Every deicing operation should include the use of an approved bucket safety harness, operational boom controls, and two way radio communication between the driver, boom operator, and wing walker(s).

Anyone operating the bucket aerial device (Boom) must wear an approved body harness affixed with an approved shock-absorbing lanyard.

Skin and Eye Protection

While glycol is not considered a toxic substance, prolonged exposure to skin may cause irritation. Also, because Type I fluid is heated up to 180° F, contact with bare skin could cause burns. Signature Flight Support requires the use of body and hand protection for employees who are deicing aircraft. The use of chemical-resistant gloves is required, and a rain suit is recommended for body protection. Employees must wash hands after exposure to glycol. Unnecessary inhalation, ingestion and/or contact with skin should be avoided.

Goggles or a facemask is recommended, but not required. If fluid should come in contact with the eyes, flush with clean running water.

Note: For employees utilizing ethylene-based glycol products, consult the Respiratory Protection Program for guidance and compliance.

Note: Eye protection is required with use of certain glycol fluids. Check the MSDS of the fluid you are using for product specifications.

Note: Cold weather often exposes personnel to temperature extremes. Having knowledge of current wind-chill factors and wearing appropriate cold weather gear can help avoid the pains of frostbite.

Note: Glycol products are very slippery. Employees must wear appropriate footwear and use extreme caution when walking on any surfaces in the vicinity of deicing/anti-icing operations.

Practice Exercise 7.3

Answer the following questions or complete the statements.

1. If communication between the bucket and driver is lost, what should occur?

____

____

2. Describe three characteristics of Type I fluid.

____

____

3. What PPE must a bucket operator have on his/her person?

____

____

Introduction

On January 2nd, 2002, N90AG, a Challenger 604, crashed on takeoff from Birmingham, England. The Air Accidents Investigation Branch (AAIB), the United Kingdom's (UK) equivalent agency to the US National Transportation Safety Board (NTSB), describes the accident in their May 2004 Aircraft Accident Report:

"Immediately after takeoff from Runway 15 at Birmingham International Airport the aircraft began a rapid left roll, which continued despite the prompt application of full opposite aileron and rudder. The left winglet contacted the runway shoulder, the outboard part of the left wing detached and the aircraft struck the ground inverted, structurally separating the forward fuselage. Fuel released from ruptured tanks ignited and the wreckage slid to a halt on fire; the Airport Fire Service was in attendance less than 1 minute later. The accident was not survivable."

Their conclusion was clear:

"It was concluded that the roll had resulted from the left wing stalling at an abnormally low angle of attack due to flow disturbance resulting from **frost contamination of the wing. A relatively small degree of wing surface roughness had a major adverse effect on the wing** stall characteristics and the stall protection system was ineffective in this situation."

Further examination into the accident found other contributing factors. The airplane had sat on the freezing tarmac overnight, accumulating a layer of hoarfrost on the wings estimated at some 1-2 mm (1/8") thick. According to the UK's Air Accidents Investigation Branch (AAIB) report, the captain asked the copilot, who was the flying pilot, about the situation (as captured on the cockpit voice recorder, CVR):

Commander: "Got a (unclear) frost on the leading edge, on there, did you look at it?"

Handling pilot: "Huh?"

Commander: "D'you (unclear) that frost on the leading edge - wings?"

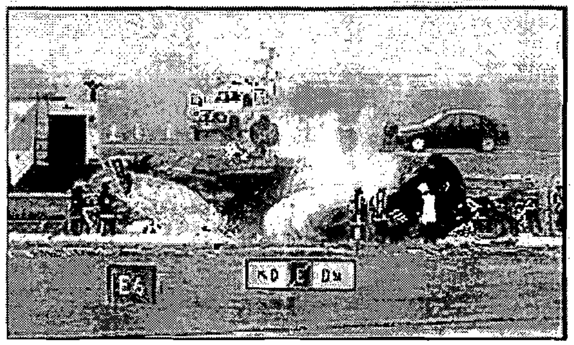
Handling pilot: "Did I feel 'em?"

Commander: "Yeah, did you - all check that out?"

Handling pilot: "Yuh."

The AAIB concluded that the crew's discussion of the icing situation was "ineffective." "The discussion on icing initiated by the captain did not adequately address the issue or arrive at an appropriate conclusion," the AAIB said.

This accident, as well as other accidents involving general aviation, business aviation and airlines dramatically illustrates the effects of frozen contamination in aircraft performance. Additionally, the Challenger 604 crash in Birmingham is especially telling in that it was a thin layer of frost that prevented a successful takeoff. While the effects of snow or ice on an aircraft seems like an obvious safety concern, frost may be hard to detect and can appear harmless. In the case of this accident, quite the opposite was true.



This Challenger 604 crash in the UK was the result of "frost contamination of the wing." It was not deiced prior to takeoff. (Photo: BBC)

Aircraft performance decreases and flight characteristics change when <u>any</u> frozen contamination is present. These changes in performance differ in aircraft design and are wide-ranging and unpredictable. Icing conditions can occur both in flight and on the ground, and winter operations procedures should be utilized when the Outside Air Temperature is below 50 degrees F (10 degrees C).

Goals of Deicing/Anti-Icing Training Program

Company Policy requires that all personnel who perform deicing/anti-icing procedures be trained annually to maintain current knowledge of deicing/anti-icing methods.

This training module, in conjunction with hands on training, will assist you with the following:

- **Deicing Equipment and Fluids**
- **Deicing/Anti-Icing Procedures**
- **Deicing/Anti-Icing Safety**
- **Deice/Anti-Ice Fluid Testing Procedures**
- **Truck Filling Procedures**
- **Fluid Storage Requirements**

Only employees who satisfactorily complete this training by passing a knowledge assessment test with an 80% or better, as well as a proficiency check, will be qualified to perform deice/anti-ice operations.

Overview of Deicing

In order to remove frozen contamination from an aircraft, a process referred to generally as "Deicing" is performed. **Deicing is a procedure by which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces.** To prevent further accumulation or refreezing of frozen contamination, "Anti-Icing" is provided. **Anti-Icing is a procedure that provides protection against the formation of frost or ice and accumulation of snow on clean surfaces of the aircraft for a limited period of time, called holdover time.** Both procedures use certain types of fluids in order to remove (Deicing) or protect against frozen contaminants (Anti-Icing).

The deicing/anti-icing process is intended to restore the aircraft to a "clean" configuration. This clean configuration is the non-contaminated aerodynamic configuration best suited for flight. A further discussion on the clean aircraft concept is contained in this module.

Fluids

The fluids used in deicing/anti-icing are propylene-based fluids which are sprayed directly onto an aircraft using a deicing vehicle, which is usually a truck equipped with a boom type device to allow an operator a maneuverable platform from which to deice/anti-ice an aircraft. There are four types of fluids generally found throughout the world, but two are most commonly used: Type I (One) and Type IV (Four).

Type I fluid is most commonly used to deice an aircraft. It is orange in color, propylene-based, mixed with water and applied heated to aircraft surfaces. Occasionally, after an aircraft has been deiced with Type I fluid, an additional application of Type I fluid is used to slow the build up of additional frozen contamination. In that context, Type I can be considered an Anti-Icing fluid as well. More often however, Type IV is used for Anti-Icing. **Type IV** fluid is exclusively an Anti-Icing Fluid. It is green in color, and it too is propylene-based. However, it is not mixed with water, is not heated and is slightly more viscous. Both fluids, but especially Type IV, are designed to increase Holdover Time or HOT. Holdover Time (HOT) will be covered in great detail in the "Deicing/Anti-Icing Procedures" portion of this module. Stated briefly, **Hold Over Time (HOT) is the estimated time deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the treated surfaces of the aircraft.**

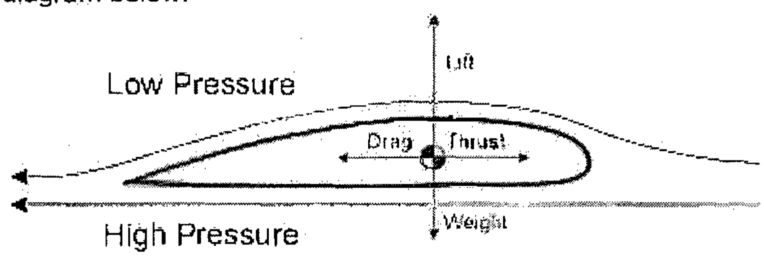
Whose responsibility is it to decide to deice?

The decision of whether or not to deice is an integral part of the process. In the Challenger 604 accident from the introduction, the crew concluded not to deice, a decision that proved fatally wrong. It is important to understand that under the Federal Aviation Regulation (FAR) Part 91.3(a), **"The pilot-in-command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft."** Although many of our customers operate under FAR 135, it should be noted that there is no difference in final authority; it rests with the pilot-in-command. As a result, it is the crew's decision as to whether or not to have their aircraft deiced. As employees we can, wherever possible, provide information to the crew that will help them make that decision. By providing information helpful to the decision-making process, you are providing a valuable service to crewmembers.

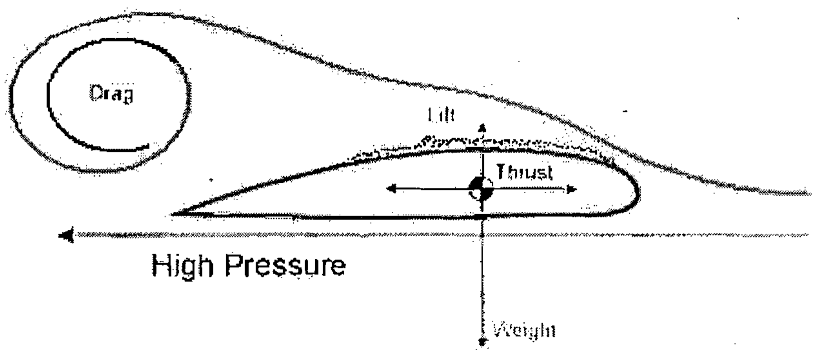
Basics of Aerodynamics

The aerodynamic principle behind how aircraft fly is still hotly debated in aviation circles, though the most generally accepted principle is Bernoulli's Principle, named for Daniel Bernoulli, a Swiss mathematician (1700-1785). The principle stems from his studies of hydrodynamics and asserts that a fluid's pressure is inversely proportional to its flow velocity. In other words, the faster the fluid moves, the lower its pressure will be. As air is a fluid (really!), it behaves in the same way any liquid would when an object, such as an airfoil, is moved through it.

Later, airplane designers using this principle realized that a wing that was somewhat flat on the bottom and curved on the top caused the air flowing over it to move faster over the top than over the bottom. As curved surfaces have more surface area, the air spreads out and must travel a greater distance over the larger surface. This has the unique effect of producing a lower pressure above the wing than below, creating lift, as illustrated in the diagram below.



In this view, a clean airfoil creates lift normally.



In this view, an airfoil that is contaminated with frozen deposits fails to create lift sufficient to overcome increased weight and drag.

Although an oversimplification of Bernoulli's Principle, when moving through the air, the wing creates a lower pressure on top than on bottom, and as a result, it is "sucked" upward into the air. This "suction" is the cause of debate amongst pilots today. The other theory usually advanced states that the wing "beats downward" the air through its Angle of Attack (AoA). For the purposes of deicing however, it is important to understand that in order for either of these theories to work in reality, both require that a wing be a smooth surface that cleanly shapes the airflow around itself rather than disturb airflow. Remember the Challenger crash conclusion reached by the AAIB stated, **"...wing surface roughness had a major adverse effect on the wing..."** It is frozen contamination in the common forms of frost, ice or snow that disturbs this airflow and causes an adverse effect on lift.

Clean Aircraft Concept

Continuing the discussion of aerodynamics, the current Federal Aviation Regulations rely on the "Clean Aircraft Concept," which has been in effect since 1950. **The Clean Aircraft Concept states, "No person may take off an aircraft when frost, ice or snow is adhering to the wings, control surfaces, propellers, engine inlets or other critical surfaces of the aircraft." A critical component is one which could adversely affect the mechanical or aerodynamic function of the aircraft.** The intent is to ensure that no one attempts to operate an aircraft with frozen deposits adhering to any aircraft component critical to safe flight. As previously noted, the ultimate responsibility for determining whether the airplane is free of contamination and complies with the "Clean Aircraft Concept" rests with the pilot-in-command (PIC). It is the employees' responsibility to ensure that the task of deicing/anti-icing is performed in accordance with the requirements detailed in this module and aircraft manufacturer manuals. For those locations serving Part 121 Air Carriers, employees must also operate in compliance with the particular Air Carrier's published deicing program.

The Clean Aircraft Concept is important because airplane performance is based on a clean aerodynamic structure, and is designed using the predictable effects of airflow over clean wings. Small amounts of contamination can add weight beyond an aircraft's design limitations and adversely effect lift. The increased weight and reduced lift can combine to create a hazardous situation.

Airflow can be disturbed by contaminants such as frost, ice, or snow on the wings resulting in:

- Reduced lift
- Increased drag and weight
- Increased stall speed
- Decreased effectiveness of flight controls
- Possible abnormal pitch characteristics
- Engine foreign object damage potential

The majority of past problems in the deicing/anti-icing process can be classified into three main areas:

- Difficulty with detecting/inspecting for ice during preflight inspections. (Crews unable to see ice due to poor lighting conditions, the transparent nature of clear ice, or ice that was otherwise hidden from view).

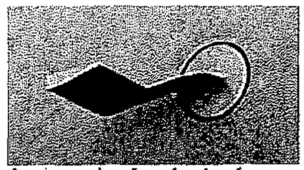
- Problems with ice removal, with verifying successful ice removal after deicing, and ice remaining on aircraft critical surfaces after deicing was completed. (All clear signals given from deicing crews).

- Procedural Problems (Deicing crews failing to follow prescribed company procedures, failing to conduct adequate post-deicing checks, poor communications between deicing crews and flight crews, improperly prepared deicing fluids, lack of reliable equipment, and inadequate staffing to conduct deicing procedures).

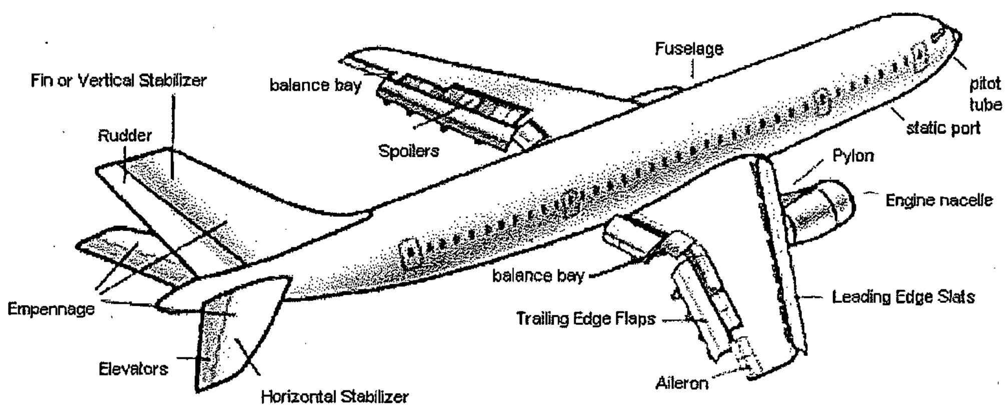
Aircraft Surfaces/Critical Components

While the wings are the main lifting surfaces of the aircraft and must be free of contaminants to operate efficiently, other aircraft surfaces must be contaminate free as well. While flight crews will often direct exactly what portions of their aircraft they wish deiced, generally, the following aircraft surfaces should be clear of contaminants in order to comply with the Clean Aircraft Concept:

- Wings - upper surface and leading edge
- Tail - horizontal stabilizer upper surfaces, leading edges and elevator upper surfaces
- Tail - vertical stabilizer and rudder
- Propellers
- Pitot Heads, Static Ports, Airstream Direction Detector Probes, Antennas, and Angle of Attack Sensors
- Engine Inlets
- Air-conditioning Inlets/Exits
- Landing Gear and Landing Gear Doors
- Fuel Tank Vents
- Fuselage (in accordance with manufacturer manuals)
- Windshields
- Flight Control Check (may be required depending on aircraft type)


An example of an Angle of Attack (AoA) probe. It is usually found on the forward fuselage.

The below diagram showing a transport category aircraft highlights specific areas that are considered "Critical Components." Additionally, the aircraft manufacturer is an excellent resource that will designate critical components for specific aircraft types.



If an aircraft is exposed to blowing snow, special attention should be given to openings where snow can enter, freeze and obstruct normal operations. These areas include:

- Pitot tubes and static system sensing ports
- Wheel wells
- Heater intakes

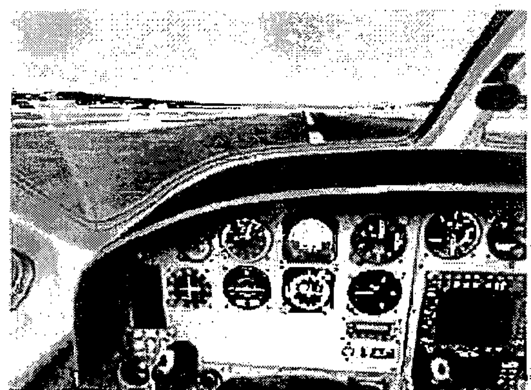
- Engine air intakes and carburetor intakes
- Elevator and rudder controls
- Fuel vents
- APU intake and exhaust

Effects of Contamination on Aircraft Services

While the contamination effects are varied and unpredictable, one thing is certain: Contaminated aircraft surfaces have been the cause of several disasters and an unknown number of "rejected takeoffs." To again reference the Challenger crash in Birmingham, one wing was likely more contaminated than the other, causing a sudden, uncontrolled roll toward the contaminated wing. Essentially, one wing was more aerodynamically "clean" than the other, causing asymmetric lift. At the time of impact, the aircraft was 111 degrees into a roll that could not be counteracted with opposite aileron input. Unfortunately, when a crew realizes an aircraft is contaminated too heavily to fly, it is often on the takeoff roll and by then, too late.

A Hazardous Scenario

As an example, depending upon whether the leading edge or the entire upper surface of the wing is contaminated with ice, stall speed (in this case the speed at which the airplane can no longer lift itself into the air) can increase anywhere from 10 percent to 35 percent. What this means is a clean (uncontaminated) wing that would normally stall at 100 knots will stall when contaminated at 135 knots. For aircraft designed to take off at about this speed, such as many business jets, the danger is obvious. Angle of attack (AOA) increases as the pilot rotates for takeoff, and into that AOA range where the wing stalls with a dramatic reduction in lift. If one wing has more ice than the other, it will stall first, leading to a sudden roll-rate at rotation.


Takeoff is the wrong time for a pilot to find out about frozen contamination.

Moreover, any significant ice sliding off the inner root of the wings on take-off can be ingested by rear-mounted engines, as can ice being shed from the side and top of the fuselage or even accumulated in the bottom of the engine inlet. The moment of rotation is also the point at which any flexing of the wings is most likely to cause upper surface ice to break loose and be immediately sucked into the engines. The result is engine surging and a massive loss of thrust. Sluggish takeoffs, black engine smoke, alarming noises from the engines, and shaking preceding nose-drop are characteristics mentioned in so many of the witness accounts of these accidents. In other words, when frozen contamination is present, lift and thrust may not be trustworthy at the critical moment of takeoff.

* Source: Aviation Safety Week, December 6, 2004.

Contamination Identification

Surface contamination comes in many forms: Ice, snow, slush and frost are just a few. Conditions that contribute to contamination may be obvious, such as falling snow, hail or sleet. Other conditions are not as obvious, but are just as important. Freezing fog and high humidity contribute to the formation of clear ice and frost. Identification of contamination is essential for proper deicing operations.

Eyes and hands are the best tools for performing contamination checks. **USE CAUTION** when touching surfaces with bare hands as the skin may stick to the freezing surface. Observations should be made as close to the surface as possible, being sure to perform checks in a well-lit area. In a dimly lit area, a flashlight should be utilized.

There are many factors that can influence the accumulation of frost, snow or ice and can also affect the abilities of deice/anti-ice fluids. Contributing factors are:

- Ambient temperature
- Aircraft surface (skin) temperature
- Fluid type, temperature and concentration
- Relative humidity
- Dew Point
- Wind velocity and direction

Contamination can be easily identified as snow or frost adhering to aircraft surfaces. Ice or icicles can form on angle of attack vanes and pitot tubes.

Frost and Hoarfrost

Frost or Hoarfrost is ice formed by the condensation of atmospheric water vapor on a surface when the temperature of the surface is below 32°F (0°C). In the formation of frost, a gas (water vapor) is changed directly to a solid. Frost often appears as a light feathery deposit of ice, often of a curious and delicate pattern.


Frost often first forms on the surfaces of hollow structures, such as in between ribs and stringers on wings.

Under clear frosty nights in winter, soft ice crystals might form on any object that has been chilled below freezing point by radiation cooling. This deposit of ice crystals is known as **hoarfrost** and may sometimes be so thick that it might look like snow. Hoarfrost might form as liquid dew that has subsequently frozen with a drop in temperature. Usually the dewdrops do not freeze immediately, even if the air temperature is slightly below zero. Rather they become supercooled dew droplets at first. Supercooled dew will eventually freeze if the temperature falls below about 23°F to 27°F (-5°C to -3°C).

Hoarfrost must not be confused with **rime**, which derives from freezing fog or glaze which forms as a continuous thick layer of ice, rather than individual frozen droplets.

Note: As a guide, if there is frost on any object (including the aircraft) and the OAT (Outside Air Temperature) and dew point are within 37.4°F (3° C) and narrowing, there is likely to be active frost. If there is a doubt, conditions should be treated as active frost.

Ice

Clear ice can form under a layer of snow or slush on both upper and under wing surfaces, normally in the vicinity of the fuel tanks, and can be a serious problem because it is difficult to see with the naked eye. By running your hand along the wing surface, in the area of the fuel tanks, you should feel the ice formation.

Clear ice typically occurs on aircraft that have flown at high altitudes for a sufficient time to cold soak the fuel in the tanks. The remaining fuel in the wing tanks is sufficient to contact the upper wing surfaces when rain or high humidity is present.

Aircraft are most susceptible to clear ice formation when:

- Wing temperatures are below 32°F (0°C) during turnaround.
- Precipitation occurs while the aircraft is on the ground.
- Frost or ice is present on the lower surface of the wing (1/8" or less is normally acceptable, anything over that must be deiced).
- Ambient temperatures between 28°F and 59°F are experienced.

Note: Extra care should be exercised when conditions are such as to cause clear ice.

Snow

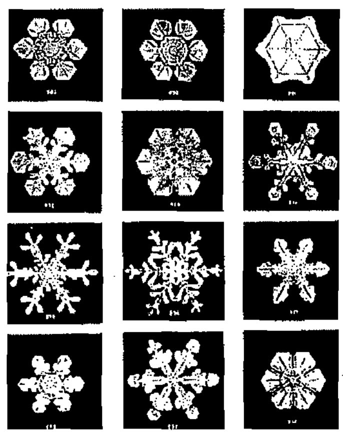
Snowflakes typically form when near-surface air temperatures are not far from the freezing mark. At these temperatures, snow crystals are more "sticky," and those that collide together will adhere to one another better than at colder temperatures. At very cold surface air temperatures, they do not stick together well at all, and thus bitter-temperature snowfalls are mostly comprised of snow crystals.

Snow crystals are formed of ice molecules and are typically 0.5 to 5 millimeters (0.02 to 0.20 inches) in size. Snowflakes are typically bigger — generally about 10 mm (0.4 inches) across and perhaps as large as 20 to 40 mm (0.79 to 1.57 inches). Exceptionally large snowflakes can exceed 50 mm (2 inches) and aggregate hundreds of individual crystals. For a snowflake to grow exceptionally large, however, conditions must be perfect. Besides ideal temperature needed for stickiness, large flakes usually only grow when winds are light; otherwise the large flakes will break up as they fall.

Using the above information on snowflake formation, it is easy to understand that local geography and weather conditions at a location will dictate the type of snowfall and the deicing methodology used to remove it. As an example, snow falling in extremely cold and mountainous locations such as Denver will generally be more "powdery" and more easily removed than snow accumulation at an East Coast location, where the air is often more supersaturated and the temperature may be closer to 32°F (0°C). In this scenario, it is a heavy "wet" snow that can grip coastal locations more readily. This is also the reason some flight crews may comment from experience that their same airplane required more or less deicing fluid to remove snow, depending on the location where they were previously transiting.

Did you ever wonder why snowflakes are six-sided?

Scientists puzzled over why snowflakes have six sides for centuries. In 1611, famed astronomer Johannes Kepler took time away from peering at the heavens to look into the small snowflakes of Earth. Writing in an essay "*On the six-cornered snowflake,*" Kepler postulated that snowflakes were made up of globules of condensed and frozen moisture — their symmetry arising from geometrical efficiency because they were well-packed arrays of tiny spheres.



It took more than three centuries to fully correct Kepler's concept. We now understand that the shape of a snowflake is first determined at the molecular level by the atoms composing the water molecule. Each molecule contains two atoms of hydrogen joined to one atom of oxygen – H_2O. In water, oxygen has a more powerful hold on the electrons that the two elements share in their water-making bond. As a result of oxygen's tighter grip, the oxygen atom side of the water molecule becomes slightly more negative while the hydrogen side becomes slightly more positive. Since opposite charges attract, the positive hydrogen atom of one water molecule tends to stick to the oxygen atom of a neighboring molecule.

In liquid and vapor water phases, water molecules jostle and dance around their neighbors, forming few stable links between molecules. But when a mass of water molecules loses enough heat energy — that is, as the water cools down toward the freezing point —the bonds (called hydrogen bonds) between water molecules form more readily and break less often.

Upon freezing, everything seizes up. Now, each water molecule is surrounded tetrahedrally by four others to which it bonds. The oxygen atoms are arranged hexagonally in layers. When a new ice forms on the growing crystal's sides, it spends less energy than if it were to add a layer on its top or bottom. The side faces advance more quickly, and the crystal structure forms. This is what provides the underlying six-fold symmetry of the crystal lattice, that grows to become the visible snow crystal or platelet of ice.

*Source: "Snowflakes," Heidorn, Keith, 2002.

Practice Exercise 7.2

Answer the following questions or complete the statements.

1. Whose responsibility is it to decide to deice?

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2. This fluid type is exclusively used for Anti-Icing.

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3. The fluid type is orange in color, mixed with water and heated.

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4. Name three types of frozen contamination that adversely affect lift.

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5. The "Clean Aircraft Concept" states...

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Definitions and Acronyms

Throughout this module, many of the below terms and acronyms are referenced frequently. It is important to become familiar with these terms and understand their implications and associations with the Deicing/Anti-icing process. Your instructor may provide additional, locally used terms. However, the terms and acronyms contained herein are industry standard terms.

Acronyms

AEA - Association of European Airlines

FP - Freezing Point

FPD - Fluid Point Depressant

ISO - International Standards Organization

LOUT - Lowest Operational Use Temperature

OAT - Outside Air Temperature

PIC - Pilot in Command

SAE - Society of Automotive Engineers

Deicing Terminology

ANTI-ICING - A procedure that provides protection against the formation of frost or ice and accumulation of snow on clean surfaces of the aircraft for a limited period of time called holdover time. (SAE Type IV fluids are normally used for anti-icing because they are thickened and provide longer holdover times. They are most effective when applied unheated and undiluted.)

BUFFER/FREEZING POINT - The difference between the OAT and the freezing point of the fluid used.

CLEAN AIRCRAFT CONCEPT – The FAA term developed in the 1950s that states, "No person may take off an aircraft when frost, ice or snow is adhering to the wings, control surfaces, propellers, engine inlets or other critical surfaces of the aircraft." The intent is to ensure that no one attempts to dispatch or operate an aircraft with frozen deposits adhering to any aircraft component critical to safe flight.

COLD-SOAK EFFECT - The wings of the aircraft are said to be "cold-soaked" when they contain very cold fuel after a flight at high altitude or from having been re-fueled with very cold fuel. (Whenever precipitation falls on a cold-soaked aircraft when on the ground, clear icing may occur.)

CRITICAL COMPONENTS/SURFACES -The aircraft surfaces, determined by the aircraft manufacturer, which shall be completely free of ice, snow, slush or frost before takeoff.

SHEAR FORCE - A force applied laterally on deice or anti-icing fluids. (Shear forces are applied whenever the fluid is pumped, forced through an orifice, or when subjected to airflow.)

DEICING - A procedure by which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces. (Heated Type I fluids are normally used for deicing to remove contamination.)

DEICING/ANTI-ICING - A combination of the two procedures that can be accomplished in one or two steps.

ONE-STEP DEICING/ANTI-ICING is accomplished with deicing fluid. The fluid used to deice the aircraft remains on aircraft surfaces to provide limited anti-ice capability.

TWO-STEP DEICING/ANTI-ICING is accomplished through two distinct steps. The first step (deicing, Type I) is followed by the second step (anti-icing, Type IV) as a separate fluid application. Anti-icing fluid is applied to protect the relevant surfaces providing maximum possible anti-icing capability.

HOLDOVER TIME - The estimated time deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the treated surfaces of the aircraft. The holdover time starts when the final application of fluid begins, and ends when the fluid applied to the aircraft loses its effectiveness. (That is, when frost, ice, or snow begins to accumulate on a surface after deicing, anti-icing, or both.)

Weather Phenomena

ACTIVE FROST - Active frost is a condition when frost is forming and occurs when aircraft surface temperature is at or below 32°F and at or below dew point.

CLEAR ICE - A coating of ice, generally clear and smooth, but with some air pockets. It is formed on exposed objects at temperatures below or slightly above freezing by the freezing of drizzle or raindrops. **Clear ice is very difficult to detect visually and may break loose during or after takeoff.**

FREEZING FOG - A suspension of numerous minute water droplets, which freeze upon impact with the ground or other exposed objects, generally reducing visibility to less than 5/8 mile.

FREEZING DRIZZLE - Fairly uniform precipitation composed exclusively of fine drops, very close together, which freeze upon impact with the ground or other exposed objects. Diameter of drops is less than .02 inches.

FROST - Ice crystals that form from ice saturated air at temperatures below 32°F (0°C) on the ground or on other exposed objects.

HAIL - Precipitation in the form of small balls or pieces of ice with a diameter ranging from .2 to >2 inches, falling either separately or joined. **There is no holdover time for this condition.**

HOARFROST - A deposit of interlocking ice crystals formed on objects. It is a uniform white deposit that occurs on exposed surfaces on cold and cloudless nights. It is thin enough to distinguish surface features underneath, such as paint lines, markings or lettering.

ICE PELLETS - Precipitation of transparent grains of ice or translucent small hail pellets of ice that have a diameter of .2 inches or less. Ice pellets usually bounce when hitting hard ground.

LIGHT FREEZING RAIN - Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, in the form of drops which, in contrast to drizzle, are widely separated. (Measured intensity is up to .10 inch/hour.)

LOCAL FROST BUILD-UP - The limited formation of frost in local wing areas sub-cooled by cold fuel or large masses of cold metal; this type of frost does not cover the entire wing. (Also referred to as Cold Soaked Wing.)

MODERATE TO HEAVY FREEZING RAIN - Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, in the form of drops which, in contrast to drizzle, are widely separated. (Measured intensity is more than .10 inch/hour.) There **is no holdover time for this condition.**

RAIN AND SNOW - Precipitation in the form of a mixture of rain and snow. For operations in light "rain and snow," treat as light freezing rain.

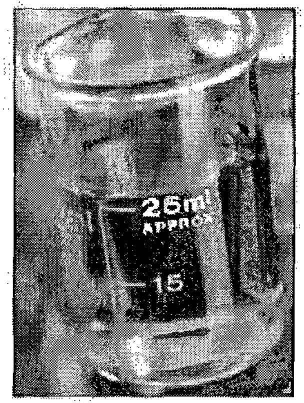
RAIN OR HIGH HUMIDITY (on a cold soaked wing) - Water forming ice or frost on the wing surface, when the temperature of the wing surface is at or below 32°F (0°C)

SLUSH - Snow or ice that has been reduced to a soft watery mixture by rain, warm temperature, and/or chemical treatment.

SNOW - Precipitation in the form of small ice crystals that are branched, star-shaped or mixed with unbranched crystals. At temperatures higher than 23°F (-5°C), the crystals join to become snowflakes.

SNOW PELLETS - Precipitation of white, opaque particles of ice that range in diameter from .08 to .2 inches. Snow pellets are brittle and easily crushed. They do bounce and may break on hard ground. **There is no holdover time for this condition.**

Fluid Testing Procedures



The use of deice/anti-ice fluid plays a major role in the safe operation of aircraft throughout the winter operations season. For this reason, fluids must be routinely sampled and tested to ensure they continue to meet industry standards. While some tests may be performed in an offsite laboratory, a number of tests are performed in the field. As a Line Service Technician, you may be tasked with performing some of these tests.

Performance of Tests

Fluid sampling occurs in the deicing/anti-icing pre-season, and is typically performed by GSE personnel. Samples are taken from the storage tank/container and from the deicing/anti-icing vehicle nozzle.

In addition to fluid samplings, fluid tests are REQUIRED to be performed as specified below:

- Upon delivery into storage from the shipper
- Prior to using the deice unit on the first aircraft of each day
- Upon completion of filling the deice unit with fluid
- After maintenance testing
- Routine examinations of Type IV fluid in storage tanks/containers
- Sudden or drastic change in OAT
- Each shift change

Delivery Tests

When deice/anti-ice fluid is delivered from the shipper, specific tests must be conducted prior to storing it in a tank/container. These tests are conducted to ensure the fluid is free from contamination and meets manufacturer specifications. Included among these tests are the following:

- Visual Contamination Test
- Refractive Index Test (Type IV)
- pH-value Test (Litmus Paper Test)

Each of these tests is described in detail later in this chapter.

Operational Tests

After the delivery test is performed, there are certain operational tests that need to be performed to ensure the fluid retains its initial deicing/anti-icing properties and is not contaminated in any way. For instance, deice/anti-ice fluid contained in a deice unit shall be tested prior to use on the first aircraft of each day. In addition, the fluid shall be tested upon completion of filling the deice unit with fluid. The person(s) performing these tasks shall perform the:

- Refractive Index Test

All test readings shall be recorded and kept on file for at least 60 days.

Note: It is also a good practice to conduct a Refractive Index Test any time there is a significant drop in temperature after the initial test on the first aircraft of the day. A significant drop in temperature may be 10^0 F or more.

After Maintenance Tests

The fluid contained in a deicing truck with repairs made to the pump, plumbing or the distribution system must be tested. In addition, fluid stored in fixed tanks/containers that are involved in maintenance or repair must be tested. The fluid is not authorized for use until testing is complete. This is a precautionary measure to ensure it did not become contaminated while the vehicle or tank/container was out of service.

The following tests shall be performed following maintenance or repair:

- Visual Contamination Test
- Refractive Index Test
- pH - value Test (Litmus Paper Test)

Routine Testing of Type IV

Routine tests must be performed on Type IV fluid in storage tanks and containers at least three times per year including the beginning, middle, and end of the winter operation season. The tests to be performed are:

- Visual Contamination Test
- Refractive Index Test
- pH – value Test (Litmus Paper Test)

If the sample drawn for testing passes all three tests, the fluid is acceptable for use. However, if the fluid fails any of the three required tests, another sample must be drawn and the fluid must be retested. If the fluid does not pass after retesting, remove the fluid from service and notify your supervisor.

Types of Tests

Visual Contamination Test

A clean, uncontaminated glass or plastic container shall be used when conducting a Visual Contamination Test. The container must be transparent for the fluid to be examined for contaminants. The fluid sample is taken by opening the product discharge slowly, allowing the fluid to fill the sample container. The objective is to get a clean, clear sample that is relatively free of air bubbles.

Once the sample is obtained, visually examine the fluid looking for any kind of contamination (e.g. rust particles, metallic debris, rubber parts, etc.). There must be no evidence of contaminants in the sample. If the fluid has a cloudy appearance, or particles floating in it, the fluid may be contaminated and must be rejected.

Note: Type IV fluid is thick and tends to trap air bubbles. When performing the visual inspection, you may observe air bubbles. This is normal.

Refractive Index Tests

The Refractive Index Test is performed with the use of a device called a refractometer, of which there are two types. The first is called a freeze point refractometer, which is orange in color and used to test Type I fluid. The second is called a Brix refractometer. This latter version is red in color and used to test Type IV fluid.

Freeze Point Refractometer

It is important to understand the components of a refractometer before describing the procedures for using the device to test Type I fluid. The freeze point refractometer consists of the following components:

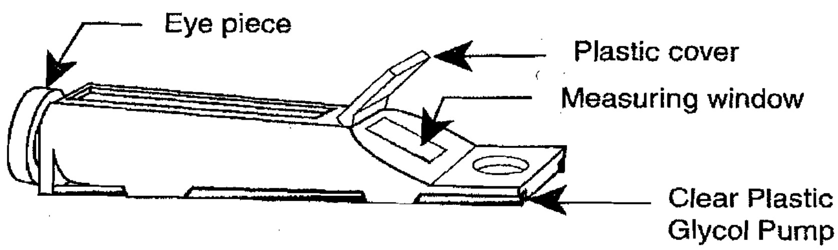
Eyepiece – Used to view scales and results of test sample.

Measuring window – Where sample fluid is placed for testing.

Plastic cover – Holds and prevents evaporation of sample while testing. If the window is left in the up position, fluid may evaporate, which can affect the reading.

Adjustment screw – Located on bottom of refractometer and used to adjust for proper reading of fluid sample.

Vinyl housing – Holds all components of the refractometer in one unit.



Prior to using a refractometer, a daily inspection shall be performed. This inspection includes looking for signs of damage such as loose lenses, ensuring the prism, cover plate, dipstick and sample tube are clean, checking the instrument for fluid penetration, and ensuring all calibration holes are properly sealed to prevent the entry of fluids or

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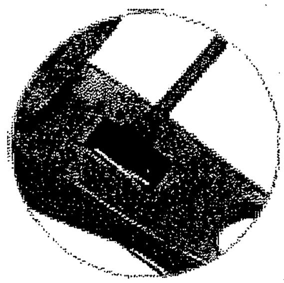
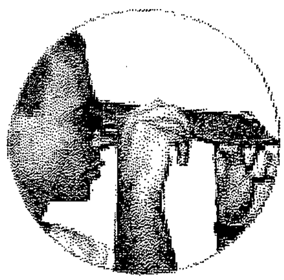
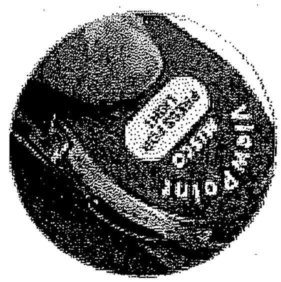
moisture. Also, be sure to note if the prism is loose by shaking the refractometer gently. If a "rattle" is heard internally, the refractometer must be serviced or replaced.

To conduct the refractometer test, place a drop of fluid from the sample or nozzle onto the measuring window (test screen) of the refractometer and close the prism. When taking the test amount from the sample jar, do not transfer any air bubbles to the glass surface of the refractometer. Bubbles will distort the results of the test.

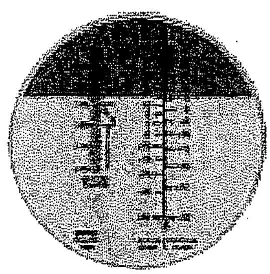


Point the refractometer toward a light source and look through the eyepiece. If the refractometer is equipped with an internal light source, activate the internal light and look through the eyepiece.





Read the value on the internal scale. Compare the value with the manufacturer's Data Summary Sheet for the fluid being tested and record the reading. If a dual scale (Ethylene and Propylene Glycol) refractometer is used, ensure the proper scale reading is taken.



When finished taking the reading, record the freeze point of the fluid on the truck sheet. Lastly, clean the refractometer and return it to the protective cover.

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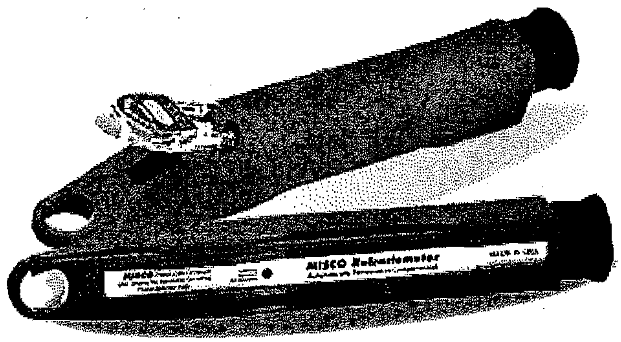


Each refractometer shall also be calibrated at the beginning of each season. GSE personnel or a supervisor/manager typically accomplishes calibration. If a large adjustment is needed, it may be necessary to return the instrument to the manufacturer for adjustment.

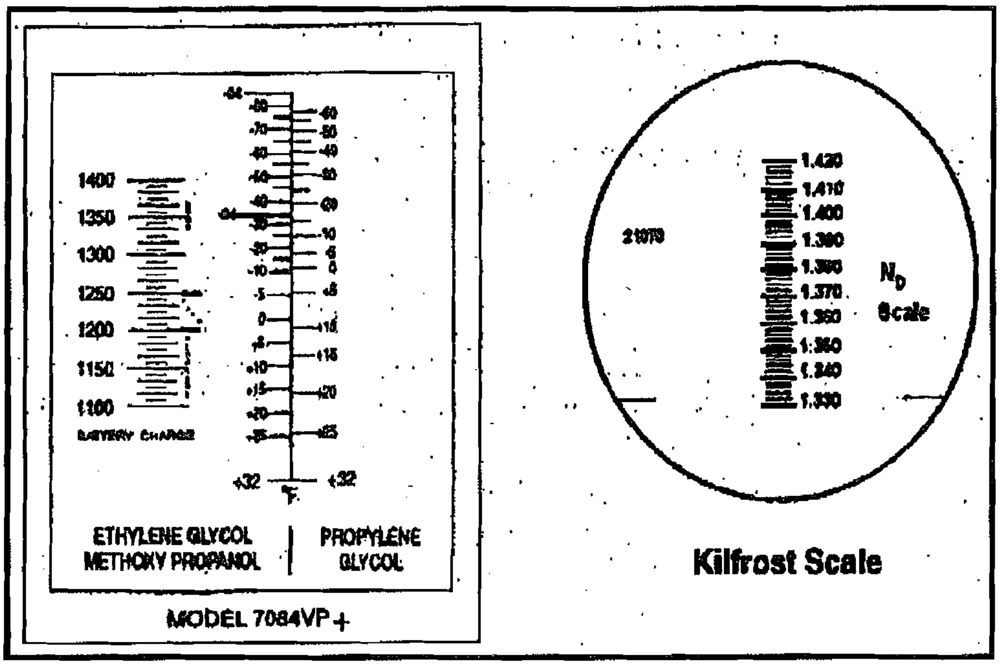
Brix Refractometer
The Brix Refractometer is designed for the accurate and rapid testing of concentrated Type IV fluid. A Brix Refractometer has the same basic components as a Freeze Point Refractometer, with one major difference. The Freeze Point Refractometer is equipped with three scales, while the Brix Refractometer has only one scale.

The Brix Refractometer must be inspected periodically and re-adjusted according to manufacturer's recommendations. Inspection and adjustment of the instrument must be made at least once a year. The recommended time is pre-season.

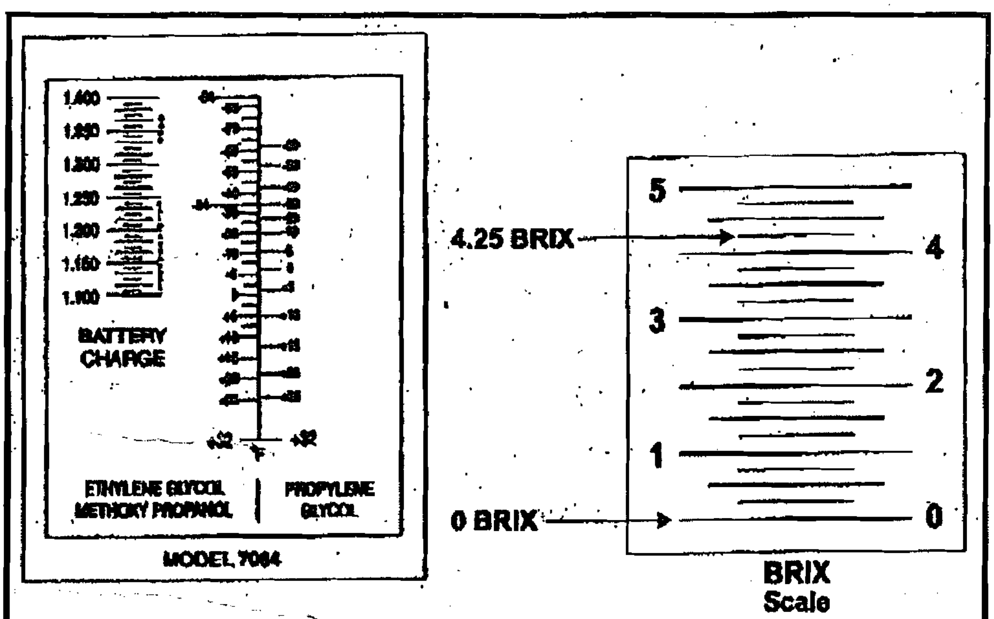
Note: If a Brix Refractometer has been dropped or abused in any way, it should not be used under any circumstances until a detailed inspection can be performed.

The Brix Refractometer shall also be calibrated at the beginning of each season. GSE personnel or a supervisor/manager typically accomplishes calibration. If a large adjustment is needed, it may be necessary to return the instrument to the manufacturer for adjustment.

Hint: A good way to remember what type of fluid a Brix Refractometer tests is this way- "Brix" has four letters– it is used for testing Type IV (four) fluid.

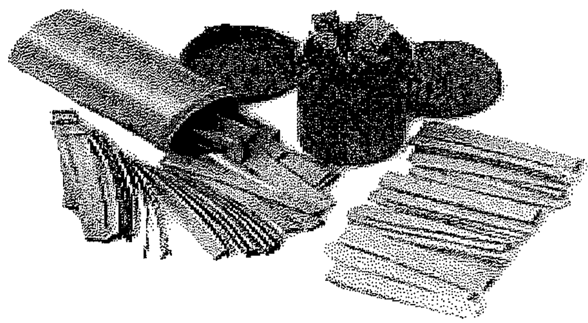


Above: An example of a Freeze Point Refractometer scale. Below: An example of a Brix Refractometer scale.



pH Value Test (Litmus Paper Test)

A pH Value Test, or Litmus Paper Test, uses a piece of litmus paper to test the pH value of the fluid. This test is conducted by dipping the paper into the fluid until it becomes wet with fluid. Once the paper is wet, colored bands on the paper will change in color according to the pH level. Compare the final colors to those on the Data Summary Sheet from the manufacturer.



Practice Exercise 7.6

Answer the following questions or complete the statements.

1. When is testing of deicing/anti-icing fluid REQUIRED to be performed?

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2. What tests are required to be performed on deice/anti-ice fluid when it is delivered from the shipper?

____

____

3. This fluid type uses a Brix Refractometer for testing.

____

4. Describe what an employee should look for when conducting a Visual Contamination Test on deicing/anti-icing fluid.

____

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